Southwest Regional Partnership on Carbon Sequestration - Phase II Field Demonstrations

Aneth Oil Field, Southeastern Utah: Demonstration Site for Geologic Sequestration of Carbon Dioxide

by

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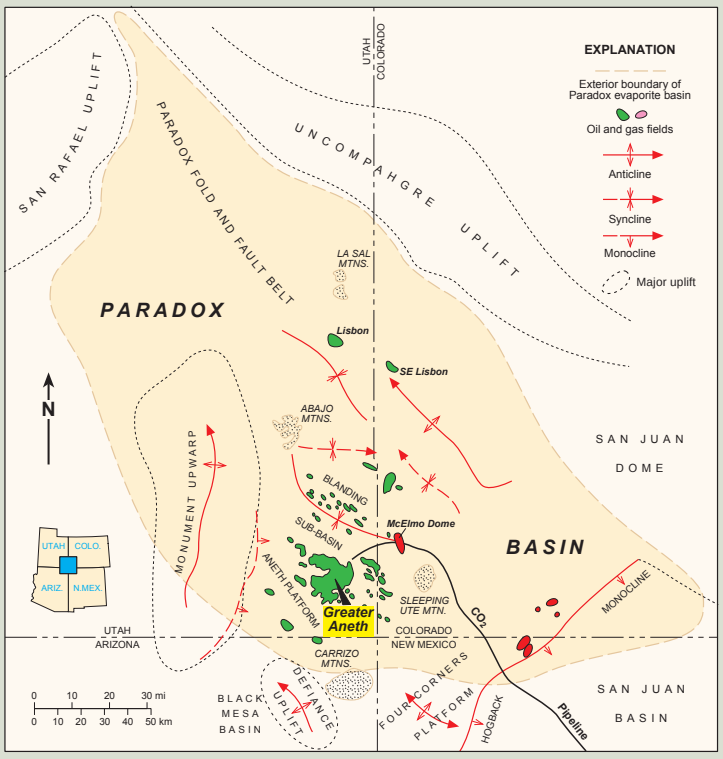
ABSTRACT

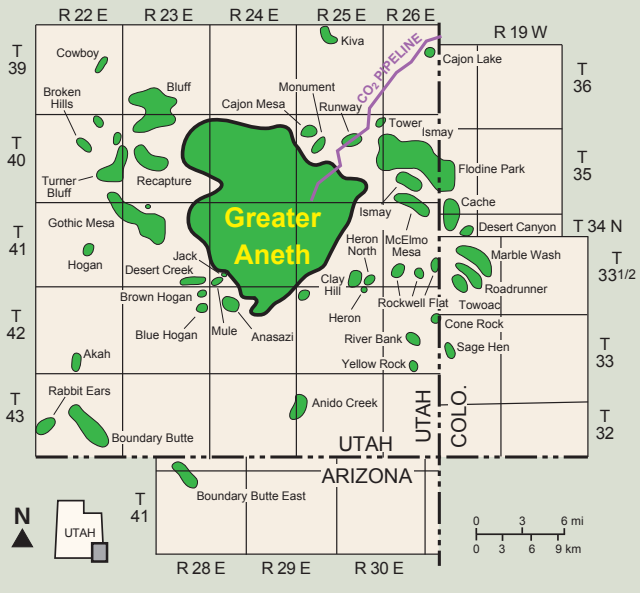
Aneth oil field, Utah's largest oil producer, has produced over 440 million barrels of oil. Located in the Paradox Basin of southeastern Utah, Aneth is a stratigraphic trap, with fractures and minor faults. Because it represents the archetype oil field of the western U.S., Aneth was selected to demonstrate combined enhanced oil recovery (EOR) and CO_2 sequestration under the auspices of the Southwest Regional Partnership on Carbon Sequestration, sponsored by the U.S. Department of Energy. This paper provides an overview of this sequestration demonstration site and how its geology will affect sequestration operations and engineering strategies.

The Aneth field demonstration will take place in the 66-km^2 Aneth Unit, operated by Resolute Natural Resources and Navajo Nation Oil & Gas Co., Inc. The primary reservoir is the Pennsylvanian Paradox Formation. Production has declined by 50% over the past 20 years in spite of waterflood and horizontal drilling projects. However, the Aneth Unit has produced 149 million barrels of the estimated 450 million barrels of oil in place - a 33% recovery rate. The large amount of remaining oil, combined with a nearby CO_2 pipeline, makes the Aneth Unit ideal to demonstrate both CO_2 storage capability and EOR by flooding the reservoir with the CO_2. The Southwest Partnership will conduct extensive monitoring to track the movement and fate of injected CO_2; risk mitigation, optimization of measurement-mitigation-verification (MMV) protocols, and effective outreach and communication are additional critical goals of the test. The planned CO_2 flood will begin in late-2006, at the rate of 400 tons/day (25 million cubic feet of gas per day [MMCFGD]).

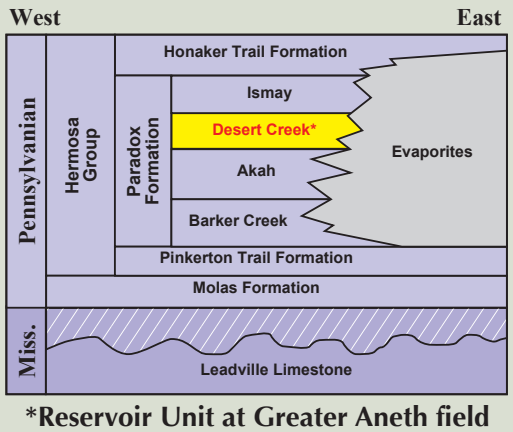
Location of the Paradox Basin and Major Oil and Gas Fields



Location of Greater Aneth and Surrounding Oil Fields, Paradox Basin

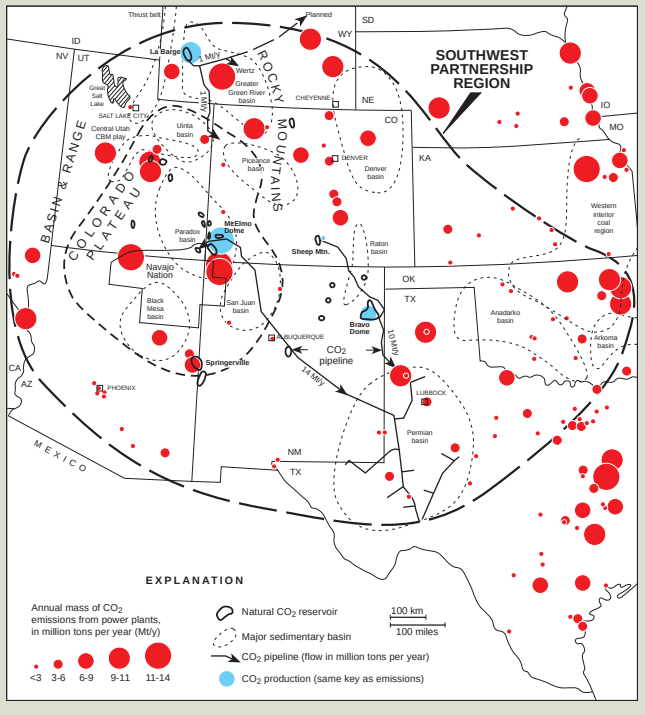


Pennsylvanian Stratigraphy of the Paradox Basin



*Reservoir Unit at Greater Aneth field

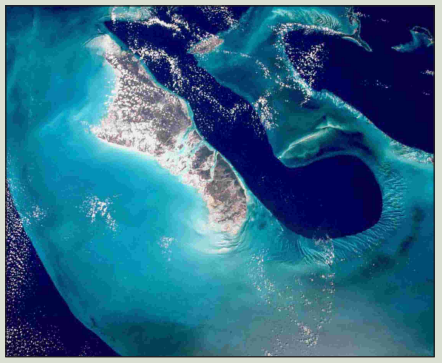
CO_2 Sources, Sinks, & Pipelines



Outcrop Analog

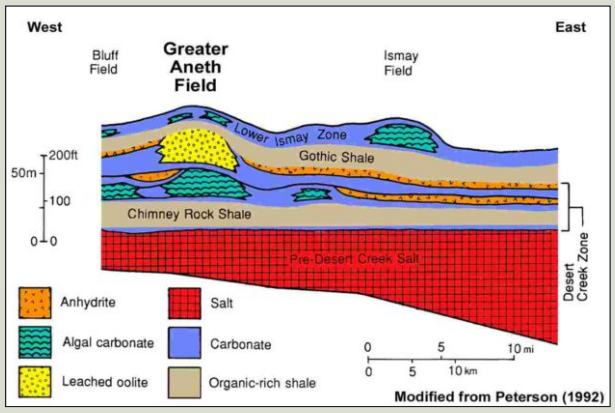
Desert Creek Phylloid-Algal Mound, San Juan River, Utah

Modern Analog

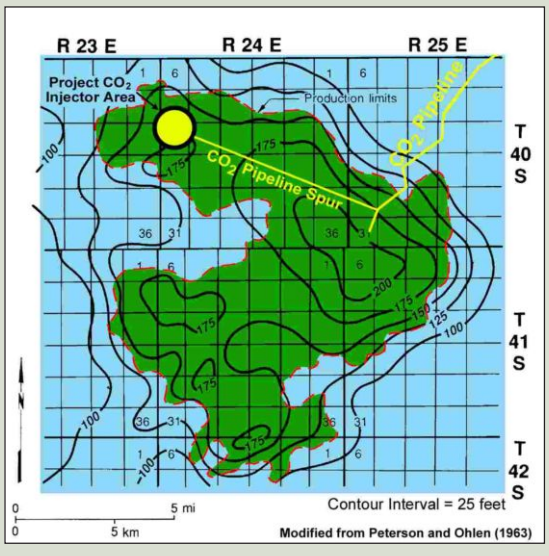


Horseshoe Atoll, Androse Island, Bahamas

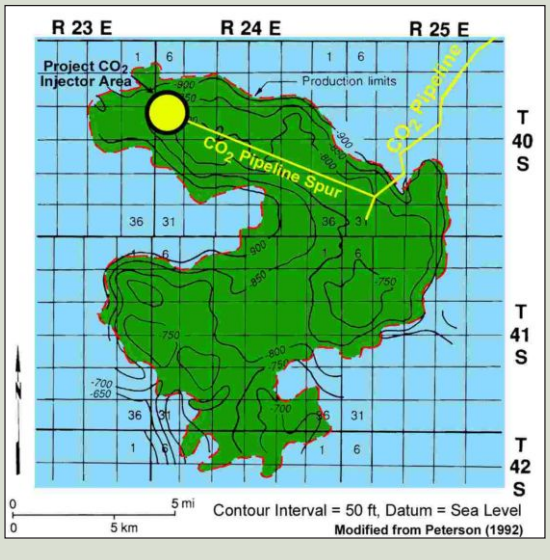
Diagrammatic Lithofacies Cross Section



Generalized Thickness Map: Desert Creek Zone



Structure Contour Map: Top of Desert Creek Zone



Discovery Well

- Texaco #1 Navajo C
- T.D. – 5923 ft
- Completed February 6, 1956
- IPF – 568 barrels of oil per day
- Initial Pressure – 2170 psia
- GOR Gas – 3448:1

Reservoir Data

- Productive Area – 48,260 acres
- Net Pay – 50 ft
- Porosity – 10.2%
- Permeability – 10 md, range 3-30 md
- Water Saturation – 24%
- Bottom-hole Temperature – 125°F
- Type of Drive – Fluid Expansion and Solution Gas
- Lithology – Limestone (algal boundstone & oolitic-, peloidal-, & skeletal grainstone & packstone), as well as finely

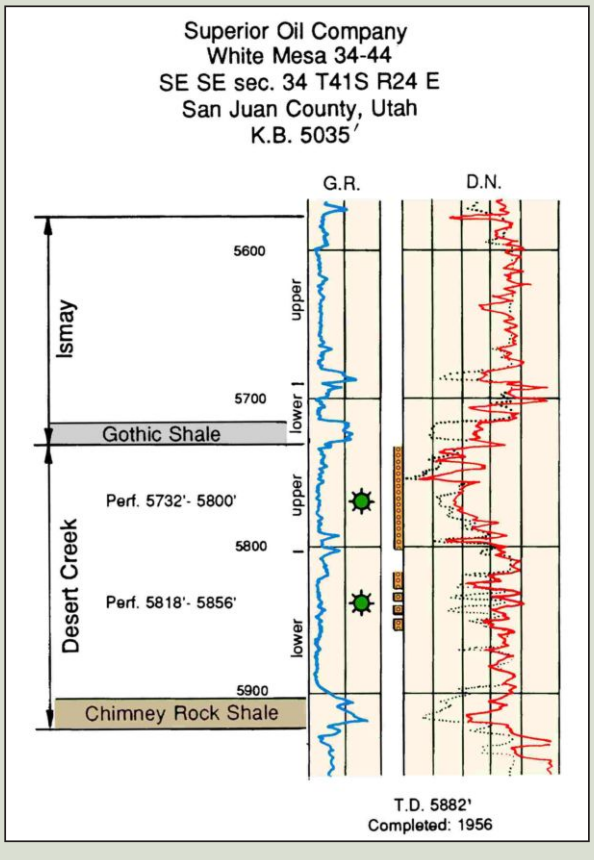
Production Data and Reserves

- Cumulative Oil – 438,657,172 barrels
- Cumulative Gas – 383,544,829 mcf
- Cumulative Water – 1,400,287,469 barrels
- Active Wells – 465
- In-Place Total Reserves – 1100 million barrels
- Type of Secondary Recovery – Waterflood and CO_2 Flood, Horizontal Drilling
- Monthly Oil Production – 285,000 barrels

Oil Characteristics

- Type – Paraffinic
- Color – Dark Green
- API Gravity – 40-42°

Greater Aneth Field Type Log



Upper Desert Creek Oolitic Grainstone

Pure Aneth 27-D4 Well Core 5620 ft

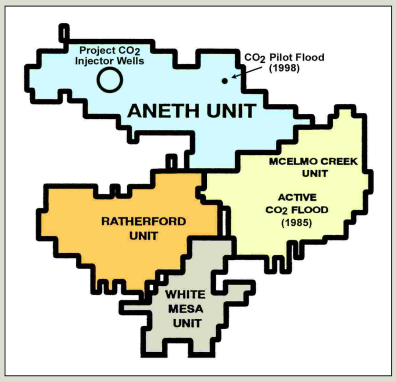
Lower Desert Creek Phylloid-Algal Bafflestone

Anasazi 1 Well Core 5651 ft

Aneth Unit

- 16,320 acres
- 421 Million Barrels of Oil in Place
- Over 149 Million Barrels Recovered (33% Recovery)
- Waterflood, 1962
- Infill Drilling to 40 acres, 1982; Infilling to 20 acres, 1988

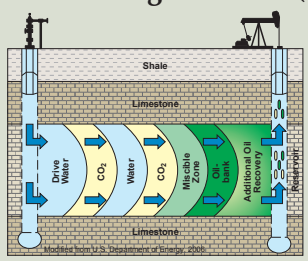
Units Within Greater Aneth Field



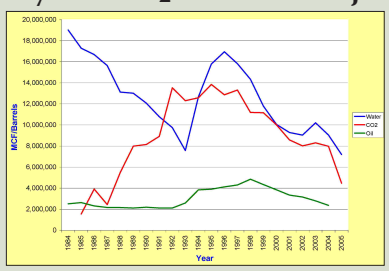
McElmo Creek Unit

- Waterflood, 1962, 4000 BOPD
- Five-Spot Pattern, 80 acre to 40 acre Infills, 1976
- CO_2 Flood (Water Alternating with Gas [WAG]), 1985,
  Increased Production from 4000 to 7000 BOPD
- Well Count
  - -Oil Producers – 90
  - -Water Injectors – 30
  - -WAG Injectors – 65
  - -Water Supply – 9
  - -Shut-In – 49
- Production Declined Since 1998
- CO_2 Cost – \$0.40 to \$0.85 per MCFG
- CO_2 Concentration – 97% Pure at McElmo Dome,

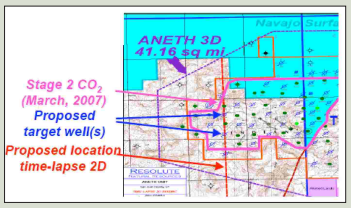
McElmo Creek Unit CO_2 Flood Program Water Alternating with Gas (WAG)

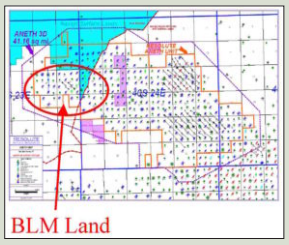


McElmo Creek Unit Oil Production History and CO_2 and Water Injection



Aneth Unit Demonstration Site

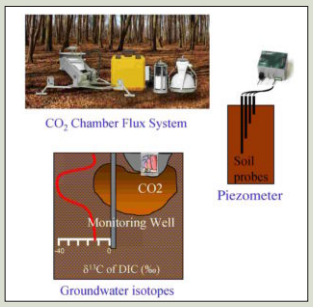




MMV (Monitoring, Mitigation, Verification)

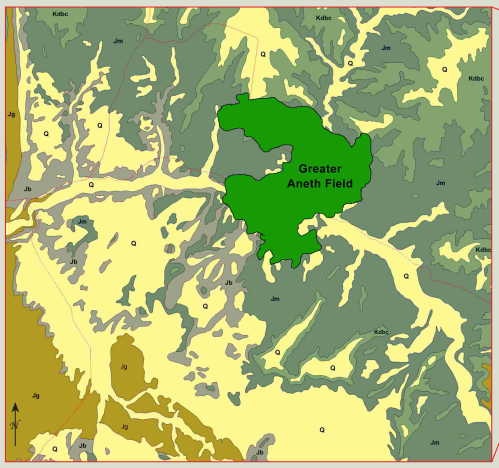
Overview

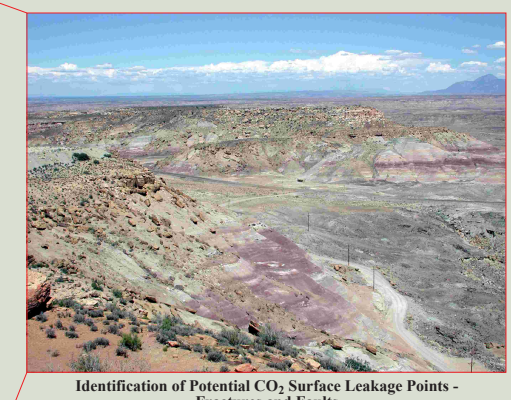
- Critically Assess CO_2 Impact to Aneth Reservoirs
  - -Verify/Predict; CO_2 Placement and Movement in Reservoir
  - -Impact to Reservoir (Reactivity, Fracturing)
  - -Monitor Any CO_2 Leakage from Reservoir
- Create Most Economic MMV Tool Set to Carry Out Tailored Approach to Reservoir Type



MMV Tools – Field Experiments (CO_2 Placement-Movement)

- **Imaging CO_2 Placement and Movement – Indirect Methods**
  - Time-lapse 2-D Seismic Reflection
  - Variations on Vertical Seismic Profiles (VSP)
  - Passive Seismic Monitoring
  - Active Doublet Methods
  - Semi-3-D Reflection Survey (aka "Poor Man's 3-D")
  - *In Situ* Pressure, Temperature, Bicarbonate
  - Coupled Models to Measurements
- **Direct Measurements of Movement:**
  - Groundwater: Trace Element, Major/Minor Ions, pH, Alkalinity, Isotopes, Inert Tracers (He, SF6, CFC's, Ar)
  - CO_2 "Piezometers": Sub-Biotic Flux
  - Surface CO_2 Flux: Chamber Measurements
  - Remote Sensing/Landsat Measurements
  - Coupled Process Reservoir Modeling
- **Site Constraints**
  - Land Ownership – Farmers
  - Permitting – Multi-Agency Federal Land
  - Access – Roads, Infrastructure
  - Geology – Complex Terrain





Identification of Potential CO_2 Surface Leakage Points - Fractures and Faults

EXPLANATION OF GEOLOGIC UNITS

Q	Quaternary	
Kdbcu	Cretaceous	Dakota Sandstone/ Burro Canyon Formation
Jm		
Jb		
Jg		

McElmo Creek Unit - CO_2 Injection Well

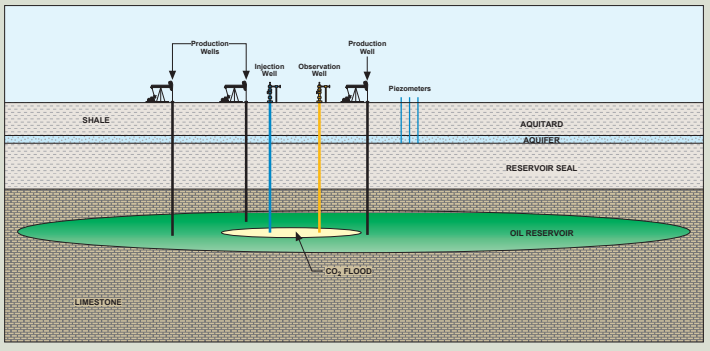
McElmo Creek Unit - CO_2 Pipeline

Specific Experiments: Aneth (2006-2009)

- **Background Monitoring (May 2006)**
  - 3-D Seismic, "Poor Man's" 3-D, VSP, Active Doublets, Passive Seismic Modeling (September 2006)
  - Ground and Produced Water Chemical Analysis, CO_2 Chamber Flux, Produced Gas Analysis, Remote Sensing (Beginning May 2006 and then Quarterly)
  - CO_2 Piezometers, Pressure-Temperature-Bicarbonate Measurements (Ongoing)
- **Injection (September 2006)**
  - 150,000 t/yr for 3.5 yrs (April 2007)
  - Ground and Produced Water Chemical Analysis, CO_2 Chamber Flux, Produced Gas Analysis, Passive Seismic Modeling (Quarterly)

MMV Tools – Field Experiments (Experimental Design)

- Observation Well: Geophones and Piezometer
- Water Wells: Transect Away from Injector Well (idea of flow path – tracer)
- Flux Stations: Transect Away from Injector Well
- Surface Seismic: Grid Above Injector Well
- Piezometers: Transects in Soil from Injector Well



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